

The University of Chicago

EFFECTS OF STORAGE CONDITIONS
ON CUT ROSES

A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY

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MARSHALL S. NEFF

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EFFECTS OF STORAGE CONDITIONS ON CUT ROSES

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 543

M. S. NEFF

Introduction

Successful storage of cut flowers should achieve several results: (a) The flowers should remain in the desired state of maturity or tightness of flower buds, during storage. (b) The flowers should retain their original color and color shadings or an equally satisfactory color, during storage. (c) It should be possible to store the flowers for a considerable period of time. (d) After removal from storage the flowers should retain their color and turgidity as long as would freshly cut flowers.

The rose, the most important flower in the florist industry, is one of the most difficult to store successfully. Under most conditions the cut buds develop characteristics that render them unsatisfactory when marketed in competition with those freshly cut. Various suggestions have been advanced toward a solution. PERRET (14) advocated the use of low temperatures and stressed the importance of the proper relative humidity during storage. HITCHCOCK and ZIMMERMAN (6) also demonstrated effects of these factors in relation to specific flowers. They stated that flowers stored at 5° C. for 7 days or longer may be expected to wilt much sooner when removed to a temperature above 20° C. than those freshly cut. NEFF and LOOMIS (13) and NEFF (11, 12) emphasized the importance of storing flowers with the flower stems out of water. THORNTON (19) found that suitable concentrations of carbon dioxide in the atmosphere of the storage container tended to prevent opening of rose buds during the storage period. Those stored in a carbon dioxide-enriched atmosphere lasted longer after removal to ordinary room conditions than similar ones that had been stored in an unenriched atmosphere. THORNTON considered 7 days the approximate limit of effective storage with carbon dioxide, because of petal drop.

The effect of storage conditions on the color of flowers has received considerable study. THORNTON (20) found that changes in the color of anthocyanin pigments of rose petals occurred when exposed to high concentrations of carbon dioxide. The bluing of the petals, that is, their tendency to become violet or purplish as they age, was correlated with changes in pH; the pH increased with the use of increased concentrations of carbon dioxide. In the case of Templar roses the loss of original color was correlated with a 0.27 increase in pH.

Change in color shading during storage is difficult to control. To overcome this

major difficulty it may be possible to stabilize the color in roses in such a way that storage conditions will not affect it. This may be accomplished eventually by treating natural coloring substances as dyes and stabilizing them in the petals, in somewhat the same manner that some dyes are stabilized. Most of the natural plant colors are mordant dyes (10, 15); that is, they must be adsorbed by a mordant or mordants if the color is to be stabilized. A mordant will adsorb a dye in the presence of a fiber (22) or combine with a dye (16) in forming insoluble colored compounds. Anthocyanin pigments, which constitute many of the colors of flowers, when mordanted with metallic salts tend to give dyeings fast to light but not to soap and water (15). Although theoretically any salt of a heavy metal is capable of acting as a mordant and adsorbing mordant dyes (10), in actual practice some salts are superior to others in this respect. Acid mordants include tannins, fatty acids, albumin, hydrous silica, arsenic acid, phosphoric acid, and various others. Metallic mordants are mainly hydrous oxides of the heavy metals, the most important of which are those of aluminum, chromium, copper, iron, and tin (22).

The color of a dye may be changed, depending on the mordant used. Alizarine red, for example, when dyed on a chrome mordant results in purplish red, on aluminum in bright red, on tin in scarlet, and on iron in a dull purple (10).

A clue to a possible role played by mordants in the living cell is suggested by the work of SHIBATA *et al.* (17). They state that organo-metallic complex compounds are formed between anthocyanin pigments and the salts of the alkaline earths and the heavy metals. They added metallic salts to solutions of certain extracted anthocyanin pigments. Such pigments extracted from *Rosa Gallica* turned red with HCl and acetic acid; violet red with CaCl_2 , SrCl_2 , MgCl_2 , and MnCl_2 ; light violet red with BaCl_2 and ZnCl_2 ; dark violet red with $\text{Al}_2(\text{SO}_4)_3$, Cr_2Cl_3 , and NiCl_2 ; red orange with $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$ and HgCl_2 ; orange with NaOH and $(\text{NH}_4)_2\text{MoO}_4$; violet with SnCl_2 and Fe_2Cl_6 ; green with $\text{Pb}(\text{C}_3\text{H}_3\text{O}_2)_2$; yellow with K_2CO_3 . In other words, the range extended from green to deep red, depending on the salt used.

SHIBATA and coworkers are of the opinion that blue anthocyanin pigments in plants are complex organo-metallic compounds, the pigments probably being coordinated with calcium or magnesium. The violet, violet red, or red pigments are considered as analogous complex compounds containing fewer auxochrome hydroxyl groups or a mixture of the blue pigment complex and a red oxonium salt. The red oxonium salt is presumably formed with an excess of acid, the anion of the acid becoming attached to the pigment molecule.

CURREY (1) investigated bluing in roses. The variety Hadley was selected as the type which often blues and Lady Maureen Stewart as the one which seldom blues. He determined that the red color in the rose petals was produced by the

formation of a red oxonium salt between the pigment and the tannins and that the tannins were the only acids found in the cell sap. He noted that Lady Maureen Stewart contained 1.9 times more pigment and 2.0 times more tannin than Hadley. The former contained 1.39 times more tannin than pigment. The Hadley rose also contained 1.39 times more tannin than anthocyanin pigment. CURREY assumed that the tendency of Hadley to turn blue was due to the fact that it contained fewer tannins than the other rose. He disregarded the fact that Hadley also had a reduced amount of pigment directly proportional to the reduced amount of tannin. It would be just as logical to assume that bluing of Hadley is due to less pigment in the petals.

CURREY also considered that the ash analysis of the two roses showed no significant differences. By recalculating his figures, however, it is obvious that Lady Maureen Stewart had 0.9 as much silica as Hadley, 1.4 times more aluminum and iron, 1.3 times more lime, 1.1 times more magnesium, 0.8 as much sulphur, 1.3 times more phosphorus, 2.4 times more soda, and 1.3 times more potash. Aluminum and iron are both important mordant elements. Lady Maureen Stewart contained more of these elements. It is possible also that the lack of salts was a factor in the bluing of Hadley.

HALL (5) reports that in dyeing, tannic acid can unite with metallic salts to form insoluble compounds and that these have the power of retaining dyes. The compounds containing tannic acid, metal, and dyestuff are more nearly insoluble and stable than similar ones in which the metallic salts are absent. PERKIN and EVEREST (15) state that the great increase of the basicity of the oxygen atom of the pyrone ring that arises in passing from the flavonol pigment to the anthocyanin pigment is presumably the cause of the latter having the power of dyeing on tannins as well as basic mordants. It is possible that organo-metallic compounds that might be formed with anthocyanin pigments increase the molecular weight of the pigment and thereby influence color (4).

A number of investigators have attempted to maintain petal turgidity and brilliant color of cut flowers by placing the stems in various solutions. DUCOMET and FOURTON (2) found that the following aqueous solutions gave positive results: sugar and sodium chloride, sugar and dipotassium phosphate, sugar and chloral, sugar and manganese sulphate. LAURIE (9) indicated that combinations of hydrazene sulphate, copper sulphate, sucrose, sodium amytal, and metallic zinc powder in proper concentrations may reduce bacterial activity, increase transpiration, lower the rate of respiration, and provide the most suitable pH and osmotic concentration. KNUDSEN (8) and HITCHCOCK and ZIMMERMAN (6) placed the stems of cut flowers in aqueous solutions containing various chemicals and found no solution of any particular value. VOLZ (21) used a solution of aluminum sulphate in water.

There are available at present at least two commercial preparations¹ for use in aqueous solutions. Both are principally sugar and aluminum salts. The length of time during which cut roses remain turgid and of good color is considerably increased by the use of these solutions. After a few days the petals of red roses lose their original color, just as do those with the stems in water, but the former maintain highly satisfactory and pleasing color as contrasted with the dull violet or bluish tinges of the latter. The petals also maintain exceptional turgidity. There is apparently no clogging of the conducting tissues of the stems; at least it is never necessary to maintain petal turgidity by clipping off the ends of the stems. This indicates a rather unusual internal physiological condition. Physiologically, aluminum salts have been reported as increasing the permeability of protoplasm, thus making it more permeable to sugars, increasing the action of diastase, slowing down photosynthesis (3), causing protoplasm to set and harden (18), and inhibiting anthocyanin production (7).

Apparently the aluminum mordant salts and sugars complement each other. If either is eliminated from the commercially available solutions, color and turgidity are not so satisfactory. With these solutions the color of the developing inner petals is affected to a much greater extent than the matured outer ones, which tend to fade and blue during storage. The solutions would be more desirable if the color of the matured outer petals were preserved. An undesirable feature of storage of roses with the stems in water or an aqueous solution is the tendency of the buds to continue to open during storage.

NEFF (12) reported favorable results in regard to the preservation of color and keeping qualities of cut roses under conditions of light, low temperature, and the use of commercially available solutions and others containing potassium nitrate and sucrose.

Experimental results

Red Hollywood rose buds stored at 32°–38° F. for any length of time have a tendency to lose the original color shadings and begin to blue. Storage at low temperature and in carbon-dioxide concentrations high enough to cause the buds to remain in a tight condition resulted in considerable tendency to blue. This was also true for roses stored at low temperature in an atmosphere containing added carbon dioxide and reduced oxygen.

Generally the petals of roses previously stored expanded rapidly after removal from storage. The petals were crinkly along the edges and seemed to lack substance. The flowers failed to remain as turgid or as well colored as freshly cut roses under similar conditions.

¹ U.S. patents 2168304 and 2230931.

TURGOR AND LOW TEMPERATURE

The manner in which roses are handled previous to storage determines to a considerable degree their response under various conditions of storage. Fresh Hollywood roses that had never been placed in water were divided into groups of six each and exposed to the drying atmosphere of a room at 32°–38° F. for 3, 12, and 24 hours. After the drying treatment, the roses were placed under bell jars to protect them from further excessive loss of moisture. The stems were not in water at any time during the drying treatment or during the remaining storage period. An additional group of roses was left with the stems in water throughout the experiment.

The roses exposed for 3 hours lost 0.46 per cent, for 12 hours 0.7 per cent, and for 24 hours 2.7 per cent of their original weight. At the end of the 12-day storage period all roses stored with the stems out of water had lost an additional 1.7 per cent of their weight.

After 12 days in storage the flowers were removed to a room at 72° F., the stems placed in water and a comparison made with fresh roses. The roses were weighed when they were first brought into room temperature and after 12, 22, 31, and 43 hours. The fresh roses gained 9.5 per cent in weight in the first 12 hours at room temperature but lost weight by the twenty-second hour. By 38.5 hours they weighed 5.4 per cent less than the original weight. The roses exposed to 3 hours of drying gained 7.7 per cent in weight the first 12 hours, 8 per cent the next 19 hours, but by the forty-third hour weighed 1.2 per cent less than their original weight. The original weight refers to the weight of the roses when first placed in storage. The buds of the stored roses opened a little more rapidly than did the fresh buds. The individuals exposed to drying for 12 hours gained 4.1 per cent in weight the first 12 hours, 4.1 per cent the next 10 hours, 2.1 per cent the following 9 hours, but weighed 6 per cent less than the original weight by the forty-third hour. The buds opened a trifle more slowly than fresh ones. Those exposed to 24 hours of drying gained 0.6 per cent in weight the first 22 hours at room temperature. The following 9 hours they weighed 15.5 per cent less than their original weight. They opened much more slowly than the fresh buds and were only half opened at the time they wilted. Those stored with their stems in water lost weight at room temperature and the buds opened faster than fresh ones.

These results suggest turgor control as a method of maintaining rose buds in a tight condition during storage. Buds opened least during storage when exposed to the drying atmosphere for 24 hours before being placed under bell jars. Twenty-four hours of drying was apparently too long, as they failed to open properly when removed from storage and placed at room temperature with the stems in water.

None of the preceding lots retained their original color shadings during storage; all had a tendency to blue. When removed to room temperature none of the storage lots retained petal turgidity or color as well as did freshly cut roses.

LOW TEMPERATURE AND CARBON DIOXIDE

Rose buds were inclosed in large metal containers and placed in storage at 32°–38° F. The tops of the containers were made with grooves which were filled with water, into which the edge of the lids fitted. This arrangement provided a water seal, preventing excessive loss of carbon dioxide. A layer of water on the bottom of the containers maintained a reasonably high humidity. The buds were stored in the containers either with their stems in water or supported on wire racks out of water. The containers were fitted with two valves, through which carbon dioxide could be introduced. Carbon dioxide concentrations of 2, 5, 10, 15, and 20 per cent were maintained. After 12–20 days of storage the roses were inferior to freshly cut ones. The chief difficulty was their tendency to blue; the higher the carbon dioxide concentrations the greater was the tendency to do so. At concentrations of 2 and 5 per cent the buds did not remain as tightly closed as when higher concentrations were used. The roses stored with carbon dioxide were inferior to fresh ones when comparisons were made as to color and turgidity under ordinary room conditions.

Sweet peas were similarly stored with stems out of water at 32°–38° F. but without the use of carbon dioxide. High humidity in the individual chambers kept the petals fresh and turgid over a 16–21-day storage period. The specimens were removed from storage in excellent condition, with no petal drop. The stored flowers were turgid almost as long as fresh blooms when subsequently placed at room temperature with the stems in water, but they had lost all odor during storage.

CARBON DIOXIDE AND REDUCED OXYGEN

Talisman rose buds were stored as previously stated in metal containers at 32°–38° F. for 5 days in atmospheres consisting of 9–10 per cent carbon dioxide and varied amounts of oxygen. To obtain the desired atmosphere, air was displaced from the metal containers by means of nitrogen gas until the desired level of oxygen was secured, then carbon dioxide was introduced. At the end of 5 days the buds stored in 4.4 and 6 per cent oxygen had opened very slightly; in 9 per cent oxygen they had opened noticeably; and in 11 per cent oxygen still more so. At the end of 5 days the roses were unintentionally frozen. This injured the stems somewhat, particularly directly below the calyx cup. The samples in 11 per cent oxygen had the least stem injury; it was progressively greater in 9 and 6 per cent, up to 4.4 per cent oxygen, where the greatest injury occurred.

LOW TEMPERATURE, LIGHT, STEMS IN SOLUTIONS

Freshly cut buds of Hollywood roses were stored in three closed metal containers (A, B, and C) in a refrigerated room at 32° - 38° F. or in two closed glass humidity chambers (D and E). High relative humidity was maintained by the layer of water on the bottom of each container. A sheet of window glass loosely placed over the top of the metal containers, in place of the metal cover, allowed for the admission of light as desired.

The buds were divided into groups of four previous to being placed in the containers. Container A received eight groups, B three groups, C two groups, humidity chambers D and E four groups. The lower portions of the stems were immersed in flasks containing Floralife, a commercial product, to which sucrose had been added at the rate of 60 gm. to a quart of solution.

Roses in container A received approximately 48 foot candles of Mazda light for an 18-day period. Container B received approximately 20 foot candles for an 18-day period. Container C was covered for the first 12 days so as to exclude light; during the last 6 days the cover was removed and the roses exposed to 10 foot candles of Mazda light. Roses in D (glass humidity cases) were illuminated by a 20-watt daylight-type fluorescent lamp. The flowers received approximately 60 foot candles of light at the surface of the petals. Container E was illuminated by Mazda light which was first passed through an aqueous CuCl_2 filter 2.2 cm. in thickness (1 gm. of CuCl_2 to 1000 ml. of water), resulting in approximately 26 foot candles of light at the surface of the petals. Light was supplied to D and E for the first 6 days of storage, then discontinued until the twelfth day, at which time illumination was resumed.

Preliminary work had indicated that if roses whose stems were in the solutions were taken from the refrigeration room from time to time it might be beneficial. Consequently groups 2 and 6 in container A, groups 1 and 3 in container B, and group 2 in container C were placed in the 72° F. room for 30-minute periods on the second, third, fourth, fifth, seventh, and eighth days of storage. Groups 3 and 7 from container A were subjected to two 30-minute periods at 72° F. on the second, third, fourth, and fifth days and one 30-minute period on the seventh and eighth days of storage. The second day of storage, groups 4 and 8 of container A were placed at 72° F. for 30 minutes for six consecutive transfers. The third and fourth days they were taken out of the storage temperature twice a day for 30-minute periods; the seventh and eighth days they were removed only once a day. Group 1 of containers A, B, C, D, and E were not removed from the storage temperature until the end of the experiment.

Roses in D and E were transferred to the 72° F. room for 30-minute periods the second day of storage in the case of groups 2, 3, and 4. On the fourteenth day of storage group 2 in case D and group 2 in case E were placed in the 72° F. room

for 30 minutes, and then at 33° F. for 30 minutes for four consecutive transfers. Groups 3 in D and E were given six consecutive transfers. Group 4 was given eight consecutive transfers of 30 minutes each.

Table 1 shows the keeping qualities of the roses after removal from storage to a room at 72° F. with the stems in water.

TABLE 1

CONDITIONS OF STORAGE AND KEEPING QUALITIES OF HOLLYWOOD ROSES AFTER REMOVAL FROM STORAGE* TO ROOM AT 72° F., WITH STEMS IN WATER. STORAGE TEMPERATURE APPROXIMATELY 32°-38° F.; HUMIDITY HIGH

CON-TAINER	GROUP	DAYS IN STOR- AGE	HOURS WITH STEMS IN SOLU- TION	HOURS IN LIGHT		FOOT CANDLES OF LIGHT		TIMES TRANS- FERRED	NUMBER OF TURGID FLOWERS PER GROUP PER DAY AFTER REMOVAL FROM STORAGE TO ROOM AT 72° F. (STEMS IN WATER)									
				MAZ- DA	FLU- ORES- CENT	MAZ- DA	FLU- ORES- CENT		DAYS									
									1	2	3	4	5	6	7	8	9	
A	1.....	8	192	192	0	48	0	0	4	4	4	2	...	...	...	...	...	
	2.....	8	192	192	0	48	0	6	4	4	4	...	...	...	...	...		
	3.....	8	192	192	0	48	0	10	4	4	4	3	...	...	...	...		
	4.....	8	192	192	0	48	0	12	4	4	4	4	...	...	...	...		
	5.....	18	432	432	0	48	0	0	4	4	1	1	1	...	...	...		
	6.....	18	432	432	0	48	0	6	4	3	3	3	2	1	...	...		
	7.....	18	432	432	0	48	0	10	4	4	4	4	4	2	...	...		
	8.....	18	432	432	0	48	0	12	4	4	4	3	3	...	...	...		
B	1.....	8	192	192	0	20	0	6	4	4	4	2	...	...	...	...		
	2.....	18	432	432	0	20	0	0	4	4	4	4	4	3	2	...		
	3.....	18	432	432	0	20	0	6	4	4	3	3	2	1	...	...		
C	1.....	18	432	144	0	10	0	0	4	4	4	4	3	1	...	...		
	2.....	18	432	144	0	10	0	6	4	4	4	2	1	1	...	...		
D	1.....	14	336	0	192	0	60	0	4	4	4	4	3	2	...	...		
	2.....	14	336	0	192	0	60	5	4	4	4	4	2	2	...	...		
	3.....	14	336	0	192	0	60	7	4	4	4	4	4	3	2	...		
	4.....	14	336	0	192	0	60	9	4	4	4	4	4	3	2	...		
E	1.....	14	336	192†	0	20	†	0	4	4	4	4	3	2	...	...		
	2.....	14	336	192†	0	20	†	0	5	4	4	4	3	3	...	...		
	3.....	14	336	192†	0	20	†	0	7	4	4	4	4	4	2	1	1	
	4.....	14	336	192†	0	20	†	0	9	4	4	4	4	4	4	3	1	...

* Fresh buds with stems in water and under room conditions remained turgid 3-4 days.

† Filtered light.

As indicated by table 1, the storage roses may remain turgid longer than fresh ones at ordinary room temperature, and those stored 18 days may remain turgid longer than those stored 8 days. HITCHCOCK and ZIMMERMAN (6) stated that flowers stored at 5° C. for 7 days or longer may wilt much sooner when removed to temperatures above 22° C. than fresh flowers. It evidently takes a certain amount of time in storage before the effect of the conditions become permanent after the flowers are removed to room temperature and the stems placed in water. This permanent effect on turgidity of petals seems to be correlated with the state

of development of the buds. Rose buds tend to open, even under conditions of low temperature, especially if they are in water or a water solution. By the fifth to seventh day of storage this tendency becomes rather marked; up to that time the buds remain relatively tight. The roses removed after 8 days of storage were one-third or less open and so had not developed sufficiently for the storage treatment to have a permanent effect on the turgidity of the petals. On the other hand, at the end of the 18-day storage period the roses were one-half to two-thirds open, so were sufficiently advanced for the storage treatment to have a permanent effect on petal turgidity.

Table 1 indicates that removing roses to room temperature for short periods of time during storage may help to maintain petal turgidity after the flowers are finally removed and placed under ordinary room conditions with the stems in water. This may be true for roses stored 18 days and receiving 48 foot candles of Mazda light, or filtered Mazda light of 20 foot candles, but not for roses receiving 48 foot candles of Mazda light for only 8 days or 20 foot candles for 18 days.

One of the effects of shifts in temperature during storage is the appearance of drops of sweet liquid which exude from stems and the veins of the leaves. Another effect is the appearance of brown spots on the petals, apparently caused by the high concentration of sugar. The roses exposed to fluorescent light showed considerably less exudation than those stored under other types of light. At the time of removal from storage there were no brown spots on the petals, when it was used. After a few hours at room temperature, however, the brown spots appeared. Another result from the use of fluorescent light is that the petals opened in a normal manner after removal to room temperature. After storage under Mazda light the petals were crinkly and definitely not normal in their subsequent development at room temperature.

SOLUTIONS

Several mixtures were developed that were successful when used in solution in maintaining petal color and petal turgidity. The solutions are basically water, sucrose, and various metallic mordants. Tables 2 and 3 list the proportions of salts and sucrose used per 50 ml. of tap water, a solution sufficient for one rose. Greatly increasing the amount of solution used per rose may result in excessive injury to the stems or petals. Better Times roses were used in these experiments.

The following sugar solutions with single salts added produced indifferent results: lead acetate, zinc sulphate, aluminum acetate, aluminum chloride, aluminum oxide, ferrous oxalate, ferrous phosphate, lead chromate, and ferrous ammonium sulphate. A sugar solution with potassium dichromate and oxalic acid and a solution composed of sugar with tannic acid and acetic acid gave only fair results.

The following sugar solutions with two salts were used with varied results. A stock solution sufficient for one rose was made up of 0.02 gm. of ferrous sulphate, 1.25 gm. of sucrose, and 50 ml. of tap water. To this basic solution was added 0.02 gm. of one of the following salts: cadmium chloride, silver sulphate, cobalt

TABLE 2

EFFECT OF SOLUTIONS* ON COMPARATIVE KEEPING QUALITIES OF FRESHLY CUT BETTER TIMES ROSES UNDER ROOM CONDITIONS; 1.5 GM. SUGAR ADDED PER ROSE

SALT PER ROSE	FERROUS CHLORIDE		FERROUS SULPHATE		CHROMIUM SULPHATE		CERIC SULPHATE		STANNOUS CHLORIDE		STANNOUS SULPHATE	
	PETALS TURGID† (DAYS)	ORIGINAL PH	PETALS TURGID (DAYS)	ORIGINAL PH	PETALS TURGID (DAYS)	ORIGINAL PH	PETALS TURGID (DAYS)	ORIGINAL PH	PETALS TURGID (DAYS)	ORIGINAL PH	PETALS TURGID (DAYS)	ORIGINAL PH
0.015.....	6	4.9	4	5.6	6	5.4	4	4.6	5	3.9	.....	.....
0.02.....		4.9	6	5.5	6	4.5	5-6	3.5	.....	.....	6	2.8
0.025.....	5	4.7	6-7	5.1	4	4.2	5-6	3.3	.....	.....		
0.03.....			6-7	5.0	4	4.0	5-6	3.0	.....	.....		
0.035.....			6	4.8	4	3.8	5-6	2.9	.....	.....		

* Similar buds with stems in water and under room conditions remained turgid 3-4 days.

† Or until they dropped.

TABLE 3

EFFECT OF SOLUTIONS* ON COMPARATIVE KEEPING QUALITIES OF FRESHLY CUT BETTER TIMES ROSES

SALT USED	SUGAR PER ROSE (GM.)	SALT PER ROSE (GM.)	ORIGINAL PH	PETALS TURGID (DAYS)	PH OF SOLUTIONS DETERMINED TWICE DAILY									
					SECOND DAY		THIRD DAY		FOURTH DAY		FIFTH DAY		SIXTH DAY	
					A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Ferrous chloride....	1.25	0.02	5.2	6	5.2	4.7	4.3	4.1†	4.9	4.7	4.7	4.8	4.7	4.7
Ferrous sulphate....	1.25	0.03	5.0	5-6	4.8	4.3	4.3	3.9†	4.9	4.4	4.6	4.6	4.5	4.4
Ferrous chloride....	0.125	0.02	5.2	6	5.0	4.5	4.1	3.8†	5.2	4.9	5.0	5.1	5.0	4.9
Ferrous sulphate....	0.125	0.03	5.1	5	5.2	4.6	4.2	4.0†	5.0	4.7	4.8	5.0	4.7	4.6
Ferrous chloride....	0.25	0.02	5.2	6-7	5.4	5.1	4.5	4.2†	4.6	4.5	4.5	4.5	4.7	4.7
Ferrous sulphate....	0.25	0.03	5.1	6-7	5.3	4.7	4.4	4.2†	5.0	4.7	4.8	4.9	4.7	4.6

* Fresh buds with stems in water and under room conditions remained turgid 3-4 days.

† Tap water added to each container, replacing water lost through evaporation and transpiration.

sulphate, cobalt chloride, sodium tungstate, uranium chloride, antimony chloride, antimony sulphate, bismuth acetate, molybdic acid, copper sulphate, ferric chloride, nickel chloride, nickel sulphate, lead chloride, manganese chloride, and mercurous chloride. Most of the solutions proved too concentrated, as shown by the

excessive burning of the stem or wilting of the petals. The use of molybdc acid, cobalt, bismuth, lead, uranium, and tin salts appeared to have promise.

Summary

1. Rose buds may be maintained in the desired state of maturity during storage at low temperature by avoiding placing the stems in water or aqueous solution during such period. The desired state of maturity also may be maintained by storing the roses in an atmosphere containing added carbon dioxide, or carbon dioxide and a reduced amount of oxygen.

2. Rose buds have a strong tendency to open during storage. This is particularly true when stored with their stems in water or aqueous solutions.

3. Roses develop objectionable color characteristics under low temperature storage. These tendencies seem to increase when stored in an atmosphere containing large amounts of carbon dioxide, or carbon dioxide and a reduced amount of oxygen.

4. As a rule, roses which have been stored do not maintain satisfactory petal turgidity or petal color after removal from storage to room temperature with their stems in water.

5. Roses which have been stored with the stems in a sugar-mordant solution under proper conditions of light and temperature and for a sufficient length of time may remain turgid longer than fresh roses when placed in water at room temperature.

6. Solutions containing water, sucrose, and a salt of certain heavy metals may materially aid in maintaining petal color and turgidity of cut roses.

DEPARTMENT OF BOTANY
UNIVERSITY OF CHICAGO

LITERATURE CITED

1. CURREY, G. S., The cause of blueing in red roses. *Jour. Roy. Soc. New So. Wales* **61**:307-314. 1927.
2. DUCOMET, V., and FOURTON, L., Preservation of cut flowers. *Florists Exch.* **31**:507-508. 1911.
3. FLURI, M., Der einfluss von Aluminumsalzen auf das Protoplasma. *Flora* **99**:81-126. 1900.
4. GEORGIEVICS, G. VON, and GRANDMOUGIN, E., The text-book of dye chemistry. Transl. and revised from 4th German ed. by A. Mason. London. 1920.
5. HALL, A. J., Dyes and their application to textile fabrics. London. 1923.
6. HITCHCOCK, A. E., and ZIMMERMAN, P. W., Effects of chemicals, temperature, and humidity on the lasting of cut flowers. *Contr. Boyce Thompson Inst.* **2**:196-203. 1930.
7. KATIC, D. L., Beitrag zur Kenntnis der Bildung des roten Farbstoffs in vegetativen Organen der Phanerogamen. Inaugural-Dissertation Halle a.S., 1905. (Cited from WHELDAL, M., The anthocyanin pigments of plants. 1916.)
8. KNUDSEN, L., Preserving cut flowers. *Amer. Flor.* **43**:649-650. 1914.

9. LAURIE, A., Studies of the keeping qualities of cut flowers. *Amer. Soc. Hort. Sci.* **33**:595-597. 1936.
10. MATTHEWS, J., Application of dyestuffs. New York. 1920.
11. NEFF, M. S., Problems in the storage of cut carnations. *Plant Physiol.* **14**:271-284. 1939.
12. ———, Color and keeping qualities of cut flowers. *BOT. GAZ.* **101**:501-504. 1939.
13. NEFF, M. S., and LOOMIS, W. E., Storage of French marigolds. *Proc. Amer. Soc. Hort. Sci.* **33**:638-685. 1936.
14. PERRET, A., Le froid en horticulture. *Rev. Sci. Paris* **5**:170-174. 1907.
15. PERKIN, A. G., and EVEREST, A. E., Natural colouring matters. London. 1918.
16. PERKIN, W. H., and KIPPING, F. S., Organic chemistry. Philadelphia. 1911.
17. SHIBATA, A. G., SHIBATA, Y., and KASIWAGI, I., Studies on anthocyanins: Color variations in anthocyanin. *Jour. Amer. Chem. Soc.* **41**:208-220. 1919.
18. SZÜCS, J., Über einnige charakteristische Wirkungen des Aluminumions auf das Protoplasma. *Jahrb. wiss. Bot.* **52**:269-332. 1913.
19. THORNTON, N. C., The use of carbon dioxide for prolonging the life of cut flowers, with special reference to roses. *Contr. Boyce Thompson Inst.* **2**:535-547. 1930.
20. ———, Changes in flower color as evidence of the effectiveness of carbon dioxide in reducing the acidity of plant tissue. *Contr. Boyce Thompson Inst.* **6**:403-405. 1934.
21. VOLZ, E. C., Studies on the keeping qualities of cut flowers. Unpublished thesis, Cornell University. 1918.
22. WEISER, H. B., Inorganic colloid chemistry. Vol. II. The hydrous oxides and hydroxides. New York. 1935.

